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An Advanced Hadron Facility: A Combined Kaon Factory and Cold-Neutron Source

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Abstract

We present a design concept for an advanced hadron facility consisting of a combined kaon factory and second generation spallation source. Our proposed facility consists of a 1.2 GeV superconducting H^- linac to bring the LAMPF energy up to 2 GeV, a multi-ring 2 GeV compressor, a shared cold-neutron and stopped-pion neutrino source, a 60 GeV 25 μAmp 6 Hz proton synchrotron, and kaon and proton experimental areas. We discuss the considerations which led to this design concept. We summarize recent results of r&d work on components for rapid-cycling synchrotrons. Finally, we mention briefly a pion linac, which may be a good way to gain experience with superconducting cavities if advanced hadron facility funding is delayed.

1 Introduction

After recent discussions, we concluded that a combined kaon factory and spallation source is a better match to the mission of Los Alamos National Laboratory than the previous LAMPF II proposal[1]. Initial considerations of the specifications and cost of a combined facility are those of the author without engineering support. The scope of this paper is limited to an overview without a detailed design.

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2 Specifications

A next generation spallation source should compete favorably with a high flux reactor. Since the existing LANSCE facility at Los Alamos is already a superb epithermal neutron source, we decided to try to optimize the new source for cold and ultracold-neutrons. We chose one megawatt of beam power with a target boost of a factor of three to give an average neutron flux equal to that of a large reactor. A repetition rate of 12 Hz was chosen to avoid frame overlap for the most interesting cold neutrons.

The neutrino physics discussion of the LAMPF II proposal led to the conclusion that either a stopped pion neutrino source or a decay-in-flight source using the highest possible proton beam energy is needed. We chose a stopped-pion neutrino source as being more interesting at the present time. Since a stopped pion neutrino source is compatible with any neutron source, we decided to combine the two facilities to minimize cost and to gain an extra factor of two in flux by operating both facilities from the same target.

Our review of the particle physics of a kaon factory showed that there is little dependence of the experimental program on proton energy above 30 GeV. However, for the highest priority nuclear physics objective, the study of quark structure of nuclei, high energy is imperative. In particular, the experiment of measuring the strange quark and anti-quark structure functions of nuclei using the Drell-Yan process requires a kaon beam energy of 30 GeV. A proton beam energy of at least 60 GeV is required to produce 30 GeV kaons copiously. Thus to serve the needs of the nuclear physics community, we chose a proton energy of 60 GeV. To keep costs at a manageable level, we reduced the beam current goal to 25 μAmp. This yields the same beam power as the previous LAMPF II design.

3 Accelerator Design Concept

The initial design concept for an advanced hadron facility is shown in Fig. 1. In order to obtain a beam power of 1 MW with 500 μAmp of beam available from LAMPF after serving the LANSCE needs, it is essential to raise the beam energy to 2 GeV. A linac is the best accelerator for this high current. Our study of linacs optimized for minimum lifetime cost showed that a superconducting linac is approximately a factor of two times cheaper than a room temperature linac at the 5% duty factor required by the existing LAMPF linac. Such a linac would be made from 4-cell 402.5 MHz superconducting cavities similar to the CERN cavities[2] (See Section 6 below).

The compressor ring is not yet designed. Our initial feeling is that a multiple ring version

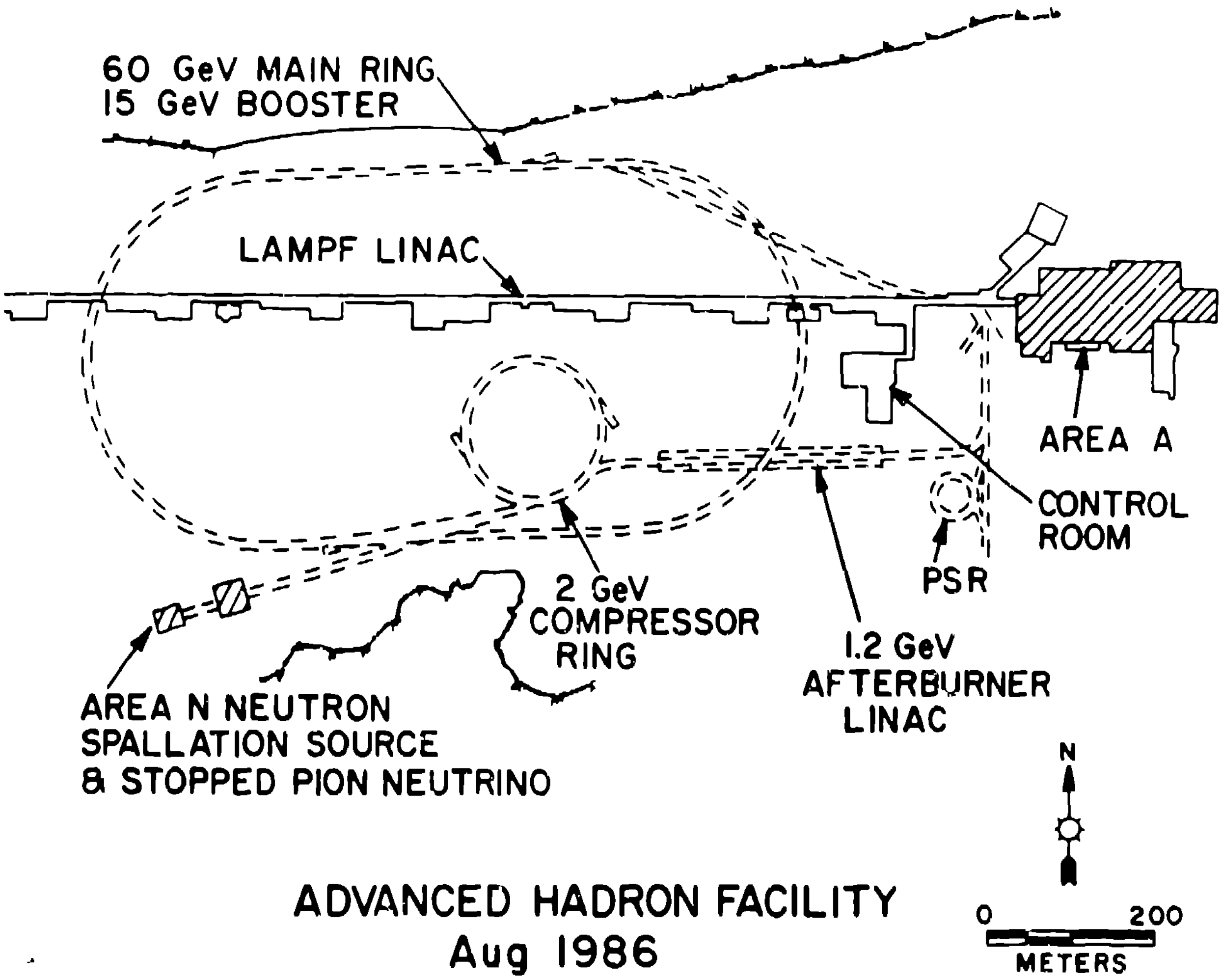

Figure 1: Proposed site layout for an advanced hadron facility.

similar to the CERN PS Booster is the appropriate choice. A five-ring compressor will provide the desired beam current at 12 Hz. Each ring will store 5×10^{13} protons, the maximum available from LAMPF in one macropulse. In this design, no ring will store more than the present PSR, which is able to avoid instabilities without active dampers. We feel that this is a more conservative approach than a single ring, which would have to contend with a serious transverse coasting beam instability.

The kaon factory synchrotrons will be injected by H^- from the LAMPF afterburner without using the compressor. Fig. 1 shows a full size booster. Such a booster is convenient since neither a main-ring flatbottom nor an accumulator ring is required. Compared with the European Hadron Facility design[3], the higher (2 GeV) injection energy allows a large bucket area at reasonable rf voltage. We may then consider a magnet power supply which transfers the magnetic energy between booster and the main ring. This reduces operating cost and eliminates all chokes and one condenser bank. To match the magnetic energy of the two rings, a booster energy on the order of 15 GeV is needed. We will also consider a half size booster and accumulator ring, as in the EHF design. A detailed cost optimization is needed to choose the injection energy and the booster energy. Such an optimization is beyond the scope of the present work.

Recent work at CERN[4] shows that the extraction efficiency of a kaon factory must be much higher than that of existing synchrotrons. In order to improve the extraction efficiency, the flexibility of a stretcher ring may be required. This will also provide a higher duty factor for the users than the previous LAMPF II design. It is likely that a stretcher ring will be a part of the AHF design, but it is not yet shown in the site layout of Fig. 1.

We have considered and rejected two adventurous alternatives. A 60 GeV proton linac scaled from the CEBAF design[5] would be more expensive than our proposed design by a factor of 12. A 60 GeV proton microtron would be somewhat cheaper, but still more expensive than the proposed synchrotrons. Such a microtron suffers from the problem that the injected beam should be highly relativistic before injection into the recirculation linac. Scaling from the CEBAF design we find that an injection energy of 100 GeV is required. We have thus demonstrated that the use of synchrotrons to reach 60 GeV is the only economically viable alternative at the present time. This conclusion will not change unless a method is found to reduce the cost of a superconducting linac by a factor of 12.

4 Cost Estimate

The addition of an afterburner linac reduces the cost of the synchrotrons by nearly the price of the linac. Thus, relative to the LAMPF II design, an AHF is more expensive by the price of a compressor and neutron source or approximately $100 million. We believe that the cost of the total facility can be kept under $500 million in 1986 dollars. A detailed design is needed to get an accurate cost estimate.

5 Progress on Accelerator R&D

A perpendicular-biased ferrite-tuned cavity is being tested to determine its maximum average power handling capability. This cavity, which has a R/Q of 35 Ohms and a tuning range greater than 20%, achieved 140 kV on a single gap at 60% duty factor in a 15 minute test. Our cavity was designed for cold tests. We are adding cooling and a vacuum window between the ferrite and the gap. After these modifications are complete, we are confident that the design specification of 80 kV at 60% duty factor will easily be exceeded.

We have tested a dual-frequency resonant magnet power supply. Full control of the flattop and flatbottom current and slope was demonstrated. A ceramic vacuum chamber with internal conducting stripes was fabricated. A laboratory for measuring the coupling impedance of vacuum chambers and other devices was established at Los Alamos. These developments are reported in contributions to this conference[6].

6 PILAC: A Pion Linac for LAMPF

A superconducting linac for pions was first suggested by D. E. Nagle in 1968 [7]. Our study of superconducting cavities led us to the observation that the present state-of-the-art is sufficient to make an attractive pion linac.

We consider a 402.5 MHz linac based on the 352 MHz CERN LEP cavities [2]. Identical cavities can be used for an AHF afterburner linac and for a pion linac. The 350 π mm-mrad phase space of the existing LAMPF P^3 pion beam [8] can be contained within a 150 mm diameter beam tube if quadrupole doublets are placed at 11 meter intervals as shown in Fig. 2. The CERN cavities scaled to 402.5 MHz will have a bore diameter larger than 150 mm.

Pion decay is a serious problem for any pion linac. The survival fraction has been given by Nagle. The results for the LAMPF case at an average gradient of 5 MeV/meter (including dead spaces) are shown in Fig. 3. From this figure, it is apparent that if a modest linac of 200 MeV is chosen, then the decay of pions will reduce the available flux by approximately a factor of 3. Even including decay, the brightness of the resulting pion beam is nearly 30 times higher than would be obtained at a conventional high energy machine such as the Brookhaven AGS. Part of the improvement comes because the longitudinal phase space of the pion beam can be rotated

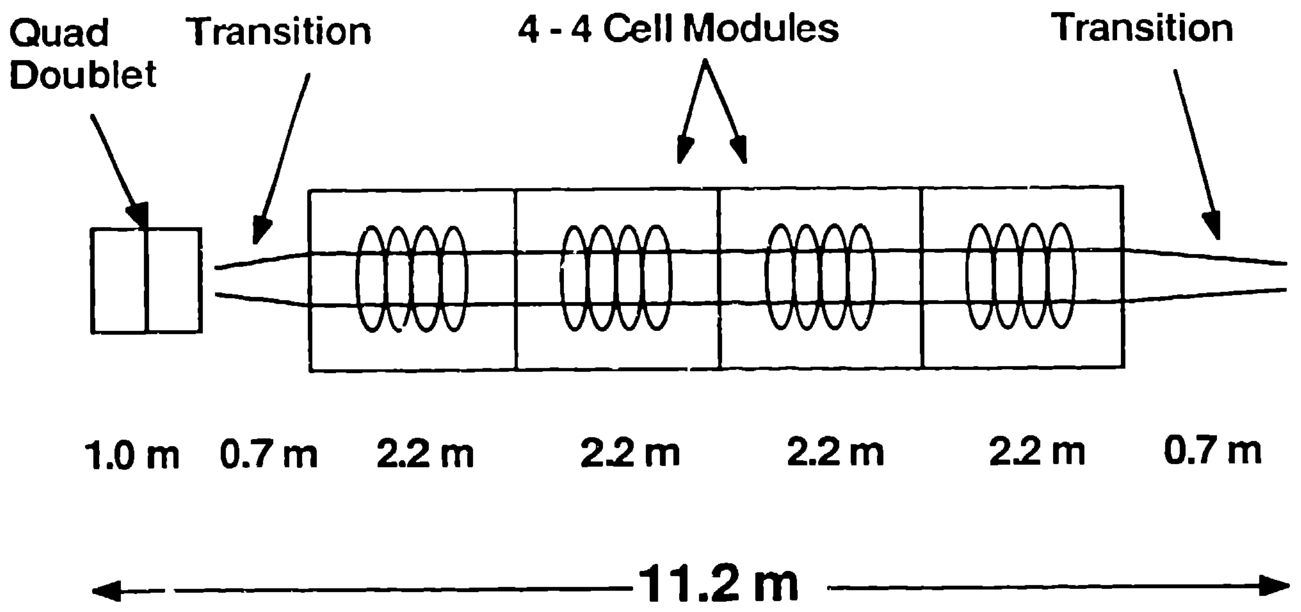

Figure 2: Proposed unit cell for 402.5 MHz pion linac at LAMPF.

by the linac to a minimum energy orientation, thus effectively compressing the 5% dp/p fwhm output of P^3 into 1%. Further, the linac acts like an rf separator since protons of the same momentum as pions will have too low a velocity to be accelerated! More details of the beam dynamics of a pion linac will be reported in the near future.

The cost of a pion linac is modest. A 200 MeV linac would raise the maximum energy of pions useable at LAMPF to 900 MeV. Such a linac could be built for $15 million. This price includes a new beam line on the output of the linac. This facility would fit in the existing staging area of Area A at LAMPF.

The issue of whether a pion linac should be built at LAMPF depends on the funding schedule of a possible AHF. If the AHF were to be built quickly, then there would be little or no time for operation of PILAC. If, on the other hand, an AHF were to be funded after CEBAF is complete and RHIC construction is well underway, then a pion linac would be a good way to get experience with superconducting cavities before tackling the more ambitious task of using them for a 1200 MeV high current H^- linac.

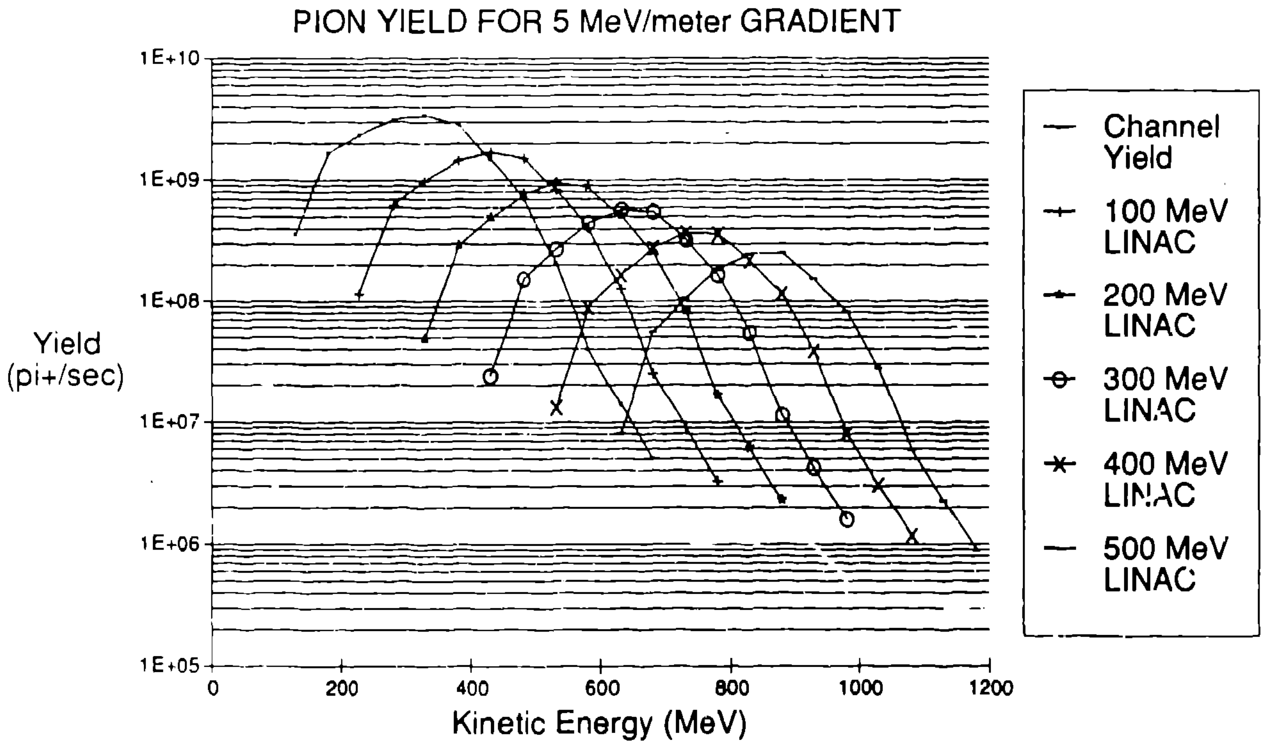

Figure 3: Yield of π^+ for Pion Linac at P^3 beam line of LAMPF.

7 Conclusions

We have shown an initial plan for a combined kaon factory and cold-neutron source at Los Alamos. Such a facility matches well the long-term goals of the Los Alamos National Laboratory, the physics community, and the materials science community. The program of accelerator r&d at Los Alamos is appropriate for an advanced hadron facility and has made substantial contributions to the state-of-the-art. There remains one important area of r&d to be started, namely, superconducting rf. We have demonstrated that in addition to their use in a LAMPF afterburner linac, superconducting rf cavities may be useful as a pion linac. A pion linac would be a sensible way to gain experience with superconducting cavities if funding for an advanced hadron facility is not possible in the immediate future.

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